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MIGRATIONS AND HABITAT OF THE TUNA (Thunnus thynnus L.) A translation

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Washington, D. C.
July, 1952

United States Department of the Interior, Oscar L. Chapman, Secretary,
Fish and Wildlife Service, Albert M. Day, Director

MIGRATIONS AND HABITAT OF THE TUNA (Thunnus thynnus L.), STUDIED BY THE METHOD OF THE HOOKS, WITH OBSERVATIONS ON GROWTH, ON THE OPERATION OF THE FISHERIES, ETC.

By Professor M. Sella
R. Comitato Talassografico Italiano, Memoria CLVI. Venice 1929

Translated by Wilvan G. Van Campen
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Migrations and Habitat of the Tuna (*Thunnus thynnus* L.), Studied by the Method of the Hooks, with Observations on Growth, on the Operation of the Fisheries, etc.

The direct evidences of the arrival of tuna from distant regions, borne by the fish itself in its own body in the form of hooks or tackle torn from the lines of fishermen, have been notably increased as a consequence of numerous investigations which I have made, to such a degree as to permit reliable deductions on some fundamental points.

There are in all (excepting some minor reports): 13 hooks and leads from the Mediterranean, which testify to the migrations of the tuna between the various basins of the Mediterranean; 25 hooks from the Atlantic (Tarifa, Northern Spain, the Azores), which demonstrate the passage of tuna from the Atlantic to the Mediterranean; and one Atlantic hook, which shows the movement of tuna from the Gulf of Gascony to Norway.

In the last two years, indeed, in addition to those which I have already made known (Rend. R. Acc. Lincei, 1926; Bull. Stat. Acquic. et Pêche de Castiglione, 1927), I have been able to recover in tuna of the Mediterranean and elsewhere, in spite of the fact that the catch of the tuna fisheries has been extraordinarily small, the following tackle:

	Tackle	Origin	Place of Recovery
1927	4 leads[1]	Constantinople	Cyrenaica (El Mongar, Bengazi)
	3 hooks[2]	Gulf of Gascony	Sicily (Favignana) and Tripolitania (Sliten)
	1 hook[3]	Azores	Sardinia (Isola Piana)
	1 hook	Gulf of Gascony	Norway (Oslofjord)
1928	1 hook[4]	South Ireland	Sardinia (Peloso)
	1 hook[5]	Gascony (probably)	Sardinia (Porto Paglia)
	1 hook	Algeria (Arzeu)	Sardinia (Porto Scuso)

1/ Three lead jigs of the "zoka" type and one lead of the "skandil" type given me by Dr. A. Benedetti.

2/ Spanish hooks for tuna and "bonito" (*Th. alalonga*). That from Favignana was given me by Comm. Caruso; the two from Sliten were found during my stay at that fishery.

3/ This and the other Sardinian hooks were given to me by the proprietors of the respective tuna traps; Marquis of Villamarina (I. Piana), Dr. de Plaisant (Peloso), Cav. Carpaneto (P. Paglia), Avv. Casaretto (P. Scuso).

4/ French double hook for "germon" (*Th. alalonga*).

5/ Spanish hook for tuna and "bonito." The origin is given as probable because at one place in Sicily (Porticello) they have now commenced making use, although on a very small scale, of hooks of this type, brought from Spain, in the fishery for albacore. This fishery lasts, however, only a few days out of the year, in the spring, and only a few boats participate in it, which removes the certainty but not the probability of the North Spanish origin of the hook in question.

To which should be added the following other reports of hooks found in previous years:

Tackle	Origin	Place of Recovery
1912 1 hook	Tarifa	Puglia (Gallipoli)
1924 1 hook	Azores	Sardinia (Isola Piana)
19-- 1 hook	Malaga	Algeria (Arzeu)

I owe the identification of the two hooks from the Azores (certain, at least, for one of them) to Major J. Agostinho, Director of the Meteorological Service of the Azores, who made an accurate investigation in the islands concerning these hooks with their typical method of tying, which it has not been possible to find anywhere else; and I owe to Dr. Ove Höeg, who took charge personally of the researches in Norway, the recovery of the North Spanish hook in the Oslofjord.

To Mr. Karekin Devedjian, I owe the certain identification of the leads from Constantinople.

In the last few years there has taken place, in respect to the type, a change in the frequency of the Spanish hooks found in the Mediterranean. While earlier the hooks from Tarifa (near the Strait of Gibraltar) were most frequent, now these have become rare and there arrive instead with relative frequency hooks for tuna and "bonito," employed by the Spaniards in Spanish waters; and this is related to the fact that the hook and line fishery for tuna at Tarifa has decayed, while that for the "bonito" in the Gulf of Gascony has had a great development. We have here an indirect proof which confirms the real origin of the hooks which are found.

Another proof of the continual movements of tuna is in the scarcity of discoveries of local hooks in the tuna captured in the same places, or in the vicinity of the places where such hooks are employed, except where there is an immediate connection in time and in the direction followed by the tuna, as I will show in speaking of the Sicilian fisheries for returning tuna.

These discoveries, while they furnish a secure basis for the primary conclusions, also permit of extension and the giving of a more general interpretation of the phenomenon of the migrations of the tuna.

1) The tuna, in the Mediterranean, cannot be separated into autochthonous groups, corresponding to different basins. -- There occurs a continuous exchange of tuna from one point to another. Naturally this does not preclude the schools' remaining for a certain time in a given sea, and therefore one may speak in a relative sense of sedentariness. Let us take for example the Adriatic. The operation of the tuna traps there shows the movements which the tuna make. The tuna commence coming from the south and from the offshore waters to the east coast of the

upper Adriatic and among the islands about the end of winter, moving in definite directions; there follows in June and July a pause in the fishing, which corresponds to the removal of the tuna for reproduction; then they reappear in August and remain until October or November. The tuna which arrive in the summer remain there, in all probability through the whole season, and one may speak of seasonal permanence. But how many of these same tuna will be represented in the suceeding year? Certainly not all, for a part take other directions. The periods in which this dispersal of the tuna is essentially determined are probably linked with the two phenomena which tend to restrict the habitat of the tuna to definite and very limited zones. The first is related to reproduction, the second to wintering. Following these the tuna again takes up its, let us say, centrifugal movement in search of food.

Without doubt then (analogously with what has been demonstrated for other fishes) a greater sedentariness is manifested in small tuna, not yet sexually mature, either because they are not yet subject to reproductive migratory drives, or because they are more resistant to low temperatures. And indeed the tuna which are captured in the winter on all coasts (and even in the Adriatic) are small or medium-sized.

One notes the interesting fact that the pattern described above for the fishery of the Adriatic is repeated, with few modifications, in all localities of the Mediterranean where tuna are fished except in the zones of the great tuna traps. Thus in the Gulf of Lyons (see statistics of Gourret, Ann. Mus. Hist. Nat., Marseilles; Roule), at Constantinople (see statistics of the fish market in Devedjian, Pêche et Pêcheries en Turquie, Constantinople 1926), on the Mediterranean coast of Spain, etc.--everywhere there occur two pauses in the fishing, that is to say in the presence of tuna: one in the winter and the other in the reproductive period.

The tuna, according to my observations, begins to reproduce in the third year of age, when it has attained a weight of about 15 kg.

With regard to the reproduction of small tuna (15-30-50 kg) I will repeat an observation which I have already made elsewhere, which is that we are still ignorant in large part as to where are to be found the areas of reproduction of the tuna of these sizes, because all of the large tuna traps take almost exclusively large fish. Do the small tuna of the Adriatic go down to spawn in the seas of Sicily? And where do the small tuna of the Gulf of Lyons go to spawn? In Sardinian or Tunisian waters, as Roule supposes? In reality we do not know: it may even happen that they do not go so far, or that they reproduce in the open sea.

2) An interesting datum on the direction followed by the returning tuna on the east coast of Sicily is furnished by the hooks from Messina.

In an investigation which I made in 1928 in these tuna fisheries (S. Panagia, Marzamemi, C. Passero, etc.), I was able to ascertain that numerous hooks from Messina (hooks which are unmistakable because of their

large size and the method of tying them, and which are very well known in Sicily) have been found in the past in the tuna taken in those fisheries, although almost all of them have been lost through carelessness. These tuna had been hooked in their passage, immediately preceding, through the Strait of Messina, where fishing is practiced as far as Scaletta and Giardini.

The traps for returning tuna fish with their mouths turned precisely toward the north, that is with the north side of the "lead," and the hooks confirm that the tuna advance precisely in that direction, from north to south. Very probably a part of the tuna which congregate in the spawning season along the northern coast of Sicily traverse the Strait of Messina and descend along the eastern coast, where they support, together with those which reproduce on the spot, the fisheries for returning tuna.

On the other hand there have hardly been any notices of hooks from Messina found in the fisheries for outbound tuna in Calabria and northern Sicily; which means that the mass of the tuna which support these fisheries do not traverse, immediately before arriving, the Strait of Messina.

3) The passage of tuna through the Strait of Gibraltar is by this time an ascertained phenomenon and, what is more important, the very large number of Atlantic hooks (25) found in the Mediterranean testifies that this occurs on a large scale. -- The idea that the tuna of the Mediterranean are separate from those of the Atlantic was so rooted from the time of Pavesi on (no less so that was the contrary theory anciently), that an effort was made to interpret my first findings of hooks as quite accidental discoveries, which could even be due to the occasional employment in the Mediterranean of hooks typical of the Atlantic on the part of sailors on sailing ships and on coastal vessels.

But my investigations would make me deny that this occurs in practice, and in any case, given the number of hooks found, elementary considerations of probability suffice here to give certainty.

The so-called proofs of the isolation of the Mediterranean have been repeated to satiety, they being that of the non-passage of the tuna through Gibraltar, and that the tuna reproduces in the Mediterranean and is found there throughout the year (Pavesi); that the number of tuna present in the other months is sufficient to be in proportion with the number which is captured in the tuna fisheries in the spawning season (Roule); that the beginnings of the seasons of the Spanish and Mediterranean tuna fisheries are contemporaneous (Pavesi), an affirmation which is not completely exact; that the number of returning tuna taken in the Spanish and Portuguese fisheries is equal to or greater than the catch of eastbound fish (De Braganca, Roule, etc.), which argument can perhaps serve, if at all, and only up to a certain point, to show that tuna once accustomed to the Spanish shores do not continue to migrate from coast to coast toward the east along the banks of the Mediterranean,

according to the theory of the ancients; but it does not serve to deny that there may be tuna which, instead of approaching Spain, enter the Mediterranean, whether to spawn or not. And also: that there are no important tuna fisheries on the Mediterranean coast of Spain, on this side of Gibraltar (De Buen); that the tuna cannot overcome the thermal and saline barrier from the Atlantic to the Mediterranean (De Buen), which is an a priori supposition, or better, which would be the explanation of a fact, if the fact were demonstrated.

None of these is a proof, and I insist on the affirmation because, in spite of their inconsistency, the attempt is made to give them the weight of proof, even against direct and incontrovertible evidence, such as that of the hooks. Such arguments prove nothing against the possibility of a spawning immigration of tuna; nothing is known concerning the non-spawning tuna.

4) Incidentally I will point out that hooks from North Spain found in tuna of the largest size, taken in the Mediterranean, permit one to deduce that the waters fronting the Cantabrian coast are visited by numerous large tuna, although all that are actually caught in those regions are tuna of small size for the most part (15-30 kg.). This might perhaps be of interest to the fishermen.

The large number of North Spanish hooks recovered in recent years is evidently related to the fact that both the hooks used for tuna in the Gulf of Gascony and those used for "bonito" (a fish which has quite a great importance there) are relatively small and attached to lines of little strength, and therefore they are easily torn off by the large tuna.

5) By means of hooks it has been possible to ascertain the presence of Thunnus thynnus in the Azores, where, as far as I know, it had not yet been recorded. -- Of the five species of tuna existing at the Azores, the most common are Th. obesus Lowe (called "albacora" there, "patudo" at Madeira, and "tuna" in the Canary Is.) and Th. pelamys C. V. ("bonito" in the Azores, "gaiado" at Madeira, and "bonito" in the Canary Is.). Fairly frequent, although less so than the preceding is Thunnus thynnus L. ("rabão" in the Azores, "rabilho" at Madeira, and "patudo" in the Canary Is.). Th. albacora Lowe ("peixe de galha à ré" in the Azores, "albacora" at Madeira, and "rabil" in the Canary Is.) is rare.[6] Very rare is Th. alalonga ("voador" at Madeira, "barrilote" in the Canary Is.).

6/ In the Canary Is. there exists another species which is similar but with the second dorsal and anal fins less developed, called "pez de ley." It is not certain whether it is a case of two distinct species or of different stages of development of the same species, the "pez de ley" being smaller than the "rabil." And thus it is even uncertain which of the two forms corresponds exactly to Th. albacora.

It has been possible for me to accomplish this homologization of the species of the three groups of islands, thanks to the precise information and the photographs with which Mr. Mario Novaro of the Canary Is., and Major J. Agostinho and Abbot E. Ferreira of the Azores have courteously favored me.

In the Canary Is. the presence of Th. thynnus, although suspected (also by De Buen: Bol. de Pescas, Dec. 1922), had not yet been demonstrated. There has not yet been any proof through hooks from the Canary Is., but nevertheless the photographs of Mr. Novaro indicate its presence with all certainty.

6) The capacity of the tuna to make great migrations is already developed in individuals of small and medium sizes (but already sexually mature). -- The tuna caught at Brucoli in 1926, carrier of a hook from North Spain, weighed 28 kg. The tuna taken in Oslofjord in 1927, carrier of an identical hook, weighed 60 kg.

This is not in contradiction to what I said at first, in a relative sense, about the probable greater sedentariness of small tuna, especially if immature. In this case we are dealing with tuna which are already adult.

7) The large number of hooks found in tuna, mostly in large ones, in relation to the limited possibility which they have of getting hooked, appears to me to be a precise indication of a condition which concerns the fishery, and that is that the number of large tuna is relatively limited and not infinite and thus in no way subject to influence by the catch, as is generally held. -- The fact is evidently related to the longevity of the tuna and to its relatively slow growth, due to which the very great number of juvenile tuna is gradually reduced by the effects of mortality.

In this connection I can anticipate some results of a study of mine of the growth of tuna, computed from the vertebrae of more than 1,500 individuals, indicating in rounded figures the annual growth (by each winter annulus completed, in individuals taken in June) in length and in weight for the first 14 years.

Age	Length[7] cm.	Weight kg.
1	64	4.4
2	81.5	9.5
3	97.5	16
4	118	25
5	136	40
6	153	58
7	169	76
8	182	95
9	195	120
10	206	145
11	216	170
12	227	200
13	239	235
14	254	280-300

These data represent some mean values from a series from Tripolitania, which do not differ noticeably from others from other regions of the Mediterranean. The values for the first two years are drawn from examinations of Adriatic tuna because the tuna fisheries of Tripolitania, like those of Sicily and Sardinia, do not capture, normally, tuna one and two years old (immature).

8) The migrations of non-spawning tuna are not influenced by salinity at least within very wide limits. -- The hooks indicate that the same tuna may frequent indifferently waters of a high saline character, like those of Ionia and Cyrenaica (38 - 38.5 0/00), as well as moderately saline waters, like those of the Atlantic (Azores, North Spain 35.5- 36.5 0/00), or those weakly saline like the Oslofjord (32 - 34 0/00[8]. But even more extraordinary is the presence of tuna in waters of a very low salinity, as are those at the surface of the Sea of Marmara and the Bosphorus: a presence not accidental, but normal, and which even supplies an important fishery (about 100,000 kg a year). Tuna are caught at Constantinople with hooks at shallow depths and also with harpoons when they come to the surface (at Arnaud Cheni and other points in the Bosphorus); this means that they occur in the current issuing from the Black Sea, which flows like a weakly saline river over a deeper stratum which has a salinity differing only by several units from that of the Mediterranean. In the Bosphorus there are salinity values of around 18.00 0/00, and to find values greater than 30.00 0/00 it is necessary to go below 40 m. (see Sta. 171, Thor, 1910, at the very point where tuna are taken with the harpoon). It is therefore certain that the tuna frequents even this upper stratum and does not keep only to the strata underneath (it further appears that tuna are numerous even in the central Black Sea). Before the absolute identity of the tuna of Constantinople

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7/ From the point of the snout to the middle point of the caudal fin, excluding the two lobes of the fin.

8/ In the Gulf of Trieste (August 1927) our analyses, made on samples collected at the same time and the same place in which the tuna were seen, gave salinities varying between 32.74 0/00 and 37.00 0/00.

and those of Cyrenaica, Tunisia, and Sardinia was established, these differences of salinity could be attributed to different adaptations, in relation to differences of race, but once the possibility is recognized that the same tuna, as an individual, may move indifferently between these various points, it is necessary to come to the conclusion that its movements are not noticeably influenced by salinity, within the very broad limits specified above.

It does not seem to me, therefore, that the theory of Roule can be maintained, according to which the tuna, even though non-spawning, although with less strictness than when ripe for spawning, tends to seek and remain in the most saline waters.

Even the strict stenohalinity and stenothermy of the ripe tuna, furthermore, in the sense maintained by Roule of a concentration of tuna on spawning grounds with maximum salinity and temperature (even if considered as limited to certain basins, for generalizing one falls into an absurdity), has not found confirmation in numerous salinity determinations (over 500) made by us in the past 2 years from samples which we had collected on 12 tuna fishing grounds in Sardinia, Calabria, Sicilia, Puglia, and Tripolitania, nor in observations of temperatures.

Therefore it can be concluded at the present time, and thus only provisionally (because to arrive at definitive conclusions it is necessary to be able to compare the conditions of several years), that the small and medium mature tuna (Calabria, Tripolitania) and the large ones (Favignana and the group of tuna fisheries of Carloforte) have somewhat different habits[9] and that the larger tuna would prefer waters relatively less saline and less warm. High salinities do not appear to be favorable to ripe tuna, and this would be one of the causes of the lack of tuna spawning grounds in the eastern Mediterranean. One should speak of seeking, not the most saline and the warmest waters, but waters having definite characteristics.

9) Is the balance between the tuna of the Atlantic and the Mediterranean influenced by the transportation of eggs and larvae through the Strait of Gibraltar?

Roule[10] supposes that if a passage of tuna through the Strait does occur, it must happen through the passive transport of larvae from the Mediterranean to the Atlantic in the deep outflowing current, these seas still remaining practically independent with regard to the adult

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9/ Even the season can be somewhat different, thus in Tunisia and Tripolitania the tuna fisheries made their catch later.

10/ Cons. Int. Expl. de la Mer, Rapp. et P.V., vol. 34; Office Sc. et Techn. Pêches Mar., Notes et Mem., No. 39.

population. Basing his belief on the established fact that larval tuna are unknown in the zones of the fisheries, he supposes that the larvae are negatively phototropic and that they go very deep to the lower strata.

It is a fact that even the Thor succeeded in its cruises in capturing only a very limited number (13) of juvenile stages, which Ehrenbaum (Danish Ocean. Exp., vol. II, 1924), who described this material, attributed only doubtfully to the tuna (and in truth, in view of material in my possession which I have already described in part elsewhere, see Rend. R. Acc. Lincei, 1924, I do not believe that they are tuna).

As a matter of fact we have taken in the Strait of Messina repeatedly, in different years, thousands and thousands of larval tuna on the surface with lights[11] and in the cruise of the Ciclope in June of 1913 along the north and east coasts of Sicily we took with plankton nets several dozen juvenile stages of tuna at different depths.

As for the tuna's being negatively phototropic, I must record the fact that the catches mentioned above, made in the Strait of Messina, have demonstrated that the juvenile stages of the tuna react violently, in a positive sense, to artificial light to such an extent that they have been taken with a simple dipnet under the light. This instinct is later modified gradually and profoundly with age. Tuna barely past the larval stage move very swiftly and therefore a special skill is necessary for their capture. In any case the short period of incubation of the tuna's eggs, and the rapidity with which the larvae and the juvenile forms not only grow but also acquire independence of movement certainly preclude the possibility of the occurrence of a passive movement of tuna from the major centers of reproduction of the Mediterranean (Sardinia, Sicily, Tunisia, and Tripolitania) to the Atlantic. At the age of 15 days the tuna may already be considered an active fish.

The situation is different in the zone adjacent to the Strait of Gibraltar, where on the Atlantic side we have a very important spawning area, while on the Mediterranean side there are no reports of any such, or at least there are no tuna fisheries. De Buen has already pointed out the possibility of the passage of eggs and larvae, emphasizing that in the region just this side of the Strait, between Ceuta and Melilla, great quantities of juvenile tuna are collected; I note, however, that the tuna of which he speaks are already fish of some size, from several hundred grams to several kilograms, that is, perfectly active and even capable of having migrated spontaneously. Tuna hatched in June already weigh 300-500 grams in September and are already taken on trolling lines.

11/ These collections were made for me by Prof. Sanzo, to whom I am indebted for much assistance in these researches.

In conclusion, if there is a passive or semi-passive movement of young tuna through the Strait of Gibraltar, it should be remembered that this occurs from the Atlantic to the Mediterranean, in respect to the position of the Iberian fisheries.

10) In a benevolent critique of my researches, Steuer (Int. Revue d. ges. Hydrob. u. Hydrogr., 1927) has pointed out the importance which the nutritive plankton-bearing currents and their fluctuations might have in determining the arrival of tuna from the Atlantic in the Mediterranean. There is a tendency, in fact, to attribute a notable importance to the migrations of planktonic forms from the Atlantic to the Mediterranean (Steuer, Jörgensen, Issel, and others).

But first of all it was necessary to ascertain whether the tuna feeds on plankton, this fish being known only as an eater of fish and large cephalopods. I will summarize the results of my researches on the food habits of the tuna.

In the tuna fisheries the stomachs of the tuna contain little food, in some cases perhaps the fish are often held in the traps for a length of time sufficient for the digestion of the animals eaten before their entrance. The tuna, however, feeds even during the period of maturation, although with diminished activity. My observations confirm those of De Buen in the Spanish tuna fisheries.

For the examination of the nutrition of the tuna outside of the spawning season I have preserved numerous stomachs of tuna caught in the Strait of Messina at various seasons. Adding the results of these examinations to the common knowledge of the fishermen, it is possible to say that the tuna:

a) Is especially an eater, even a ravager, of the most important schooling pelagic fishes of small size: in the Mediterranean above all the sardine, the anchovy, the Clupea aurita, the mackerel, the Trachurus, and the Belone acus; in the north the young herring, etc., and even of some fishes of somewhat larger sizes like Auxis, Th. alalonga, and in the north the Gadus (Hanson). Thus the occasional capture of the tuna on hooks in the North Sea and in some places in the Mediterranean is subordinate to the fishery for the species which are eaten (sardine, anchovy, mackerel, herring). Only in a few places has it the importance of a special fishery (Constantinople, the Canary Is., Madeira, the Azores, Messina, Arzeu, Tarifa, San Sebastian, Cristiansund).

The tuna feeds also on fishes which are coastal or rarely migratory like the salpa (Box), various murenoids including the eel, etc., and in addition on large cephalopods like Loligo and Sepia.

b) Is also an eater of true macroplankton, in particular of heteropods (Pteritrachea, Carinaria), pyrosomas and salpas, and of decapod

crustaceans, isopods, and schizopods.

Among these latter Meganyctiphanes norvegica and Euphausia Kronii Brandt (so diffused in the Mediterranean as to influence notably in many places the total quantity of macroplankton: Jespersen) have a special importance; shoals of these traverse the Strait of Messina in the autumn and winter and the tuna appear so glutted on them that under these conditions they let themselves be easily approached and harpooned by the fishermen.

It appears therefore likely that these and other forms, widely distributed in the Atlantic, forming regular shoals, can actually influence by their fluctuations and migrations from the Atlantic to the Mediterranean the routes, the concentrations, and the distribution of the tuna in the latter sea.

I note the analogy with Thunnus alalonga, which, in the Atlantic, is distributed in relation to the shoals of an amphipod, Euthemisto bispinosa Boek (Joubin and Roule; Le Danois).

The planktonic feeding of the tuna probably also facilitates its exodus from the Mediterranean and contributes to its enormous range, which would be very restricted if its food habits were strictly linked to certain pelagic fishes, divided into races of limited geographic habitat, as for example the Clupeidi or the Scombri of the Mediterranean, which are distinct from those of the Atlantic.

It further appears that the tuna does not pursue indefinitely the same schools of fish. In the Strait of Messina it gives chase successively to the fishes which are passing through there, in autumn to the young anchovies, in winter to the eels, and then to the "costardelle" (Scombresox), etc.

11) In regard to the preceding, we can ask whether the fluctuations in the balance of tuna between the Atlantic and the Mediterranean may be such as to affect the production of the tuna fisheries. But this discussion involves the whole complicated study of the fluctuations in the catch of the fisheries and of their causes. It must not be forgotten that the tuna traps catch fish in spawning condition and that therefore we should expect to find the production of the fishery influenced especially by oceanographic conditions, both local and general, of a physical and chemical nature.

More than by the abundance of tuna present at a given moment in the Mediterranean (which reflects also, at a distance in time, the conditions under which the generations of tuna in different years develop), the catch of the tuna trap fisheries is influenced by the greater or lesser degree in which the tuna come close in to the coast and by the geographical dispersions which occur in the areas of maturation.

Neuparth, (A Pesca Maritima, No. 2, 1923, Lisboa) examining the statistics of the tuna fishery of Medo das Cascas, considers that it is possible to recognize a cycle of a century in the catch of the Portuguese fisheries. De Buen (Biología del Atún, Madrid 1925) starts out from some very old statistics, those of Padre Sarmiento, to deny that there is any periodicity whatever identifiable in the catch of the Spanish tuna fisheries.

The statistics of Padre Sarmiento do not appear to me to be worthy of attention, and in any case I would not base on them conclusions contrary to more recent and more reliable statistics. Apart from the suspected progress of the fishery, it must be demanded how Sarmiento came to get hold of the data for hundreds of years while even today we cannot succeed in gathering complete statistics, and one must remain incredulous in the face of the catch of 70,000 tuna taken repeatedly from a single fishery (a figure which, actually, is little surpassed in certain years by all of Spain, Italy, and Portugal put together). Probably these 70,000 tuna included also some smaller fishes. ... How could a tuna trap fishery take and salt down more than 1,000 fish every day?

For my part I have tried to gather all accessible statistical material, resorting even to private records and to researches in Archives. The most complete statistics are these:

Sardinia

Fishery of Carloforte;	complete data	since	1825	and	fragmentary	earlier
Saline	"	"	"	1868	"	"	"

Sicily

Favignana	"	"	"	1878	"	"	"

Tunisia

Sidi-Daud	"	"	"	1863			

Portugal

Medo das Cascas	"	"	"	1852	"	"	"
Barril	"	"	"	1867	"	"	"

There are besides official Portuguese statistics from 1896, Italian from 1886, and Tunisian from 1898.

From this examination various facts emerge which can be summarized thus (see the diagram in Fig. 1):

a) The tuna fishery in Italy and in Tunisia has undergone a secular fluctuation, in which in Sardinia and Sicily one can identify a peak in the second half of the 18th century, a low point around 1820-1830, and a new high, in which Tunisia also participated, around 1880, with a new

low at the present time, a low which has brought the fishery to its present grave crisis.

b) This secular fluctuation corresponds to that which has occurred in the same period in Portugal. And from the general indications which we have it would appear that the fishery in Spain has also had in the last century an analogous progress down to the present low point, from which it has begun to recover only in the past two years.

This fact is quite important for us because it can be interpreted in the sense that the Mediterranean tuna fisheries are subject to the same general influences which determine analogous fluctuations of great amplitude in the Atlantic fisheries, and that therefore the Mediterranean fisheries are subject to the oceanographic influence of the Atlantic, which can only be manifested in the influx of water from the Atlantic through the Strait of Gibraltar.

It is in fact not very probable, although still not precluded, that it is a question of influences of a meteorological or other nature, operating synchronously but separately in the two regions.

This is one of the many cases which show how useful would be an oceanographic observatory at the Strait of Gibraltar, the idea of which was suggested by Steuer, which would gather data for the study of the relations between the two seas and of the seasonal and annual variations.

c) The secular fluctuation of the Lusitano-Mediterranean tuna fisheries corresponds with the last secular fluctuation of the herring fishery at Bohuslän, described by Pettersson and Johansen, except for a lag of several years.

And I note that the existence of these fluctuations has been recognized for many centuries now (Ljungman). Pettersson relates it to secular variations in the tides (111 years). Storrow has also occupied himself with the question, placing in evidence analogous fluctuations for other fishes. It is admitted, in any case, that these phenomena are provoked by changes which take place successively and alternately in the physical conditions of the waters.

The analogy between the fluctuations of the Mediterranean tuna fisheries and the herring fishery in the Skagerrak appears to conform very well to the concept expressed above that our tuna fisheries reflect Atlantic influences. And the proven antiquity of the phenomenon which occurs in Scandinavia augments the probability that that of the tuna fisheries has had a periodic character.

d) There are specific zones in which the overall effect of the secondary fluctuations of the tuna fisheries, at least those of a certain amplitude, present a marked analogy. One of these zones embraces all of Sardinia and Tunisia (Sicily with Favignana is separate from it although very near).

Thus the sudden drop in the catch at Sidi-Daud around 1895, which Roule attributes to heavy rains and to the fresh water carried by the outlet of the lake of Bizerte, situated 50 km to the west, finds a more plausible explanation in the analogy of habit with Sardinia.

e) With the method of the analysis of modes worked out by Vercelli, (Atti Congresso Soc. It. Progr. Scienze, 1928) there are evident, for some tuna fisheries, fluctuations which are periodical or at least of almost constant period, of various magnitudes. Thus the curve of the catch of the two Sardinian fisheries of P. Scuso and P. Paglia, taken together, turns out to be composed of periodic elements of 2, 3-4, 6, 10, 24, and 100 (?) years. The relative calculations for this series were made by Prof. Vercelli himself.

For Sidi-Daud also, it was possible to show fluctuations of quite similar period.

Naturally the study of the cases, in part local, in part more or less general, is still all to be done.

Granted that the curve of the catch of certain tuna fisheries may be entirely broken up into periodic or almost periodic elements, it is possible to make predictions for some of them.

It is a pity that these statistics, with few exceptions, are very badly kept. The fishery with tuna traps, because of the uniformity of the means (fishing season, position and dimensions of the constituent nets) would lend itself better than any other to analyses of this nature.

Meanwhile, in a general way, it is possible to give assurances to the operators of the tuna fisheries that the crisis which has vexed the fisheries of the Mediterranean for some years is certainly transitory. Apart from fluctuations of lesser magnitude, we are now at the bottom of a cycle of a century (or at least a very long period), and once that is passed over such unfavorable conditions for the fishery will probably not return for several score years.

12) The result which is perhaps most interesting in connection with the method of the hooks, is that which leads to the recognition of the existence of a vast area frequented by tuna of identical race. It is this which permits one to attempt an overall outline of the movements which the tuna make in connection with reproduction and feeding.

This area embraces the Mediterranean, about half of the North Atlantic as far as the Azores, and the North Sea, from about the latitude of the Tropic or a little farther north to the Arctic Circle at the other extreme.

The tuna is not very common at the Canaries (where the other purely Atlantic or more tropical species of tuna predominate) and certainly it does not push much farther south along the coast of Africa. To the north it is common in the region of Trondhjem in Norway and it has been seen frequently at Lofoten.

In the Catalogue of Fishes of the North Sea, edited by the Conseil perm. p. l'Exploration de la Mer (Publ. Circ. n. 12), there is a record of the occasional presence of tuna on the Murman coast, a notice of which I do not know the source, and which I judged to be extraordinary before I came into possession of the following information. Dr. Höeg wrote me, in fact, that in August 1927, the geologist Dr. Th. Vogt saw in the Laksefjord of Finmark, beyond North Cape, a school of about 20 tuna, and he learned on the spot that the phenomenon was not a new one.

The tuna probably even frequents the waters of Iceland, because the bones of tuna have been found on those coasts.

Do our tuna cross the Atlantic and is there an interchange of tuna between Europe and America? It is taken in Canada (Nova Scotia) and on the North Atlantic coast of the United States, where it even appears to be very abundant. I have launched an appeal to the American sporting clubs and in the Canadian Fisherman (March 1927) in order to try to recover hooks found in tuna on the other side of the ocean, but without any success up to the present time.

The affirmation that the area characterized by means of tuna carrying hooks, converging in the Mediterranean, is the habitat of a single race of tuna may still appear too bold, but in reality only two hypotheses are possible: either that of a single race, or that of the coexistence of local races together with a race diffused over the whole area. And the second hypothesis seems worthy of little attention.

With regard to somatometric investigations of tuna from different regions, in 1913 I took multiple measurements on 50 tuna from the fishery of S. Petri in Spain, measurements which I immediately repeated on a similar number of tuna from Calabria and Tripolitania, without finding variations sufficient to set apart distinct races. I hope in another work to re-examine my measurements in comparison with those taken by Heldt on Tunisian tuna (Ann. Station Ocean. Salammbo, N. IV, 1927), publishing my data; but there cannot be any difference between the tuna of Tripolitania and the bordering Tunisia.

This identity is also confirmed by the rates of growth, practically equal for Spain and for different regions of the Mediterranean, while it is known that the growth of Atlantic and northern races, for fish in general, is greater than that of the Mediterranean races. Thus even the hypothesis brought forward by Steuer, of the possible existence of a large Atlantic race and a small Mediterranean race of tuna is eliminated.

I note that such a belief is prevalent among many tuna fishermen for the curious reason that in certain traps they catch small tuna and in others large tuna, while in reality one encounters all of the intermediate sizes.

If, then, the tuna which inhabit all of the immense area described above belong to the same race, the reproductive act, which is that which determines the physiological reactions most typical of the species, will take place in identical conditions, with the movement of the tuna to the same spawning grounds. We do not know all of these areas, and I believe that there is much to be discovered in this field, but we have no indication of their existence outside of the Mediterranean (and even of a part of that sea) and outside of a limited part of the Atlantic bordering on Spain.

Taking into account the results of the fishery in the North Sea, we can schematize the movements of the adult tuna as follows (Fig. 2);

a) In May-June groups of tuna are within the restricted area of spawning situated toward the southern limit (Mediterranean, Spanish waters). In this period the tuna are absent from the northern seas and even (although not completely so) from the northern coasts of the Mediterranean, with secondary differences of time due to differences of habit between the small and large tuna.

b) Successive movements which are centrifugal, or more exactly, which are directed essentially toward the north, with dispersion of the tuna throughout all of the vast area of their habitat. The maximum geographical diffusion takes place in the hottest months of summer-autumn, and especially in September, at least in the Mediterranean. The first tuna appear in the North Sea at the beginning of July.

c) A new reduction of the habitat with the coming of winter. We have little information on the extent of the winter habitat of the tuna, because this is accompanied by a certain shift to deeper levels, but it probably undergoes a notable reduction and in any case, in the north and in the Atlantic, a displacement, because the tuna disappear completely from the North Sea after November or a little later. On the coasts of the northern Mediterranean all of the large tuna and almost all of the small ones move offshore.

d) In the period March-April, immediately preceding the spawning season, the tuna make a new migration, but much more limited than that of the summer and autumn, toward the north. The tuna reappear en masse on the north coasts of the Mediterranean, and in the Atlantic we find them again on the Spanish coast of the Gulf of Gascony; I do not believe that tuna have been sighted farther to the north at this season.

Then there is a new concentration in May and June and a new dispersal from the zones to the north. The small tuna absent themselves a little later, that is in June or July.

There take place, then, two movements of dispersion, the first after wintering, the second, much more extended, after spawning.

The habitat of the tuna appears to be regulated in large part by the Gulf Stream; in fact this coincides (even in the United States and Canada, where the tuna is lacking in the part subject to the cold Labrador current), with the area in which the current of the Gulf makes its influence felt. Evidently the presence of tuna north of Norway, at the polar limits, can only be explained thus.

We can, to a certain extent, evaluate even the speed at which the tuna are capable of dispersing, and can find confirmation that the fish possess physical powers which render them able to make these great seasonal wanderings, in the following fact. At Cristiansund in Norway, where the arrival of the tuna is now checked by capable fishermen and observers, the first tuna arrive in the first week of July, exceptionally at the end of June. I have information from private sources to the effect that Mr. Hanson caught a tuna which still showed traces of recent spawning.

These tuna certainly come from the southern zones of reproduction, of which the nearest is in Spanish waters or, in any case, not appreciably farther north. The tuna never spawns before June. One can, then, calculate that in less than one month the tuna makes a journey, certainly not direct, from the south of Spain to Norway.

Interesting, too, is the observation of Hanson (Cfr. Höeg, in Il Risveglio della Pesca, n.8, 1927, Milano), that in Norway regularly the large tuna appear first and then the small ones, with a lag of about 3 weeks. I consider this to be precisely in accord with the fact which I have ascertained in the Italian and Tripolitanian fisheries, that the large tuna (around 100 kg or more) mature and release their sexual products before the small tuna (15-30-50 kg); and actually the spawning of the large tuna is finished at the beginning of July, while that of the small tuna continues to the end of that month or a little longer, in the fishery for returning tuna. Also the disagreement noted above between the classical spawning season of the tuna (May-June) and the period in which actually the greater part of the tuna move off from the northern coasts of the Mediterranean (June-July) results from this fact.

Among the direct proofs, then, of the movement of tuna from north to south for reproductive purposes in the Mediterranean, it seems to me that the most suggestive is that of the four leads from Constantinople, found in a single fishing season (1927) and in different individuals, in tuna from the fishery of El Mongar near Bengazi in Cyrenaica, which cannot be explained except by the arrival en masse in Cyrenaica of individuals coming from the Sea of Marmara and the Bosphorus.

Proposal to the Congress

1) For the study of the migrations of the tuna, I propose that in agreement with our Spanish colleagues provisions be made for the marking of a certain number of hooks of the Spanish type for fishing for tuna and

"bonito," to be distributed free to the fishermen of the Cantabrian coast; as Dr. Heldt announced that he had done with French double hooks for the "germon" fishermen in Brittany.

The present researches have shown that the former is the type of hook which is actually found most frequently in the tuna, while the recoveries of French double hooks are rarer, perhaps because these latter, not having any barbs, are more easily lost.

2) Taking up an idea of Dr. Steuer's, and considering the fundamental importance which oceanographic influences and influxes of plankton from the Atlantic have in certain types of biological phenomena, I propose a vote of approval "for the creation of an oceanographic observatory in the Strait of Gibraltar, with the mission of collecting periodically all of the oceanographic data which may serve in the study of the reciprocal relations between the two seas, including the transit of plankton, and for a knowledge of their seasonal and annual variations."

(Communicated to the Int. Congress of Oceanography, Hydrography, and Hydrology of Seville, 1929).

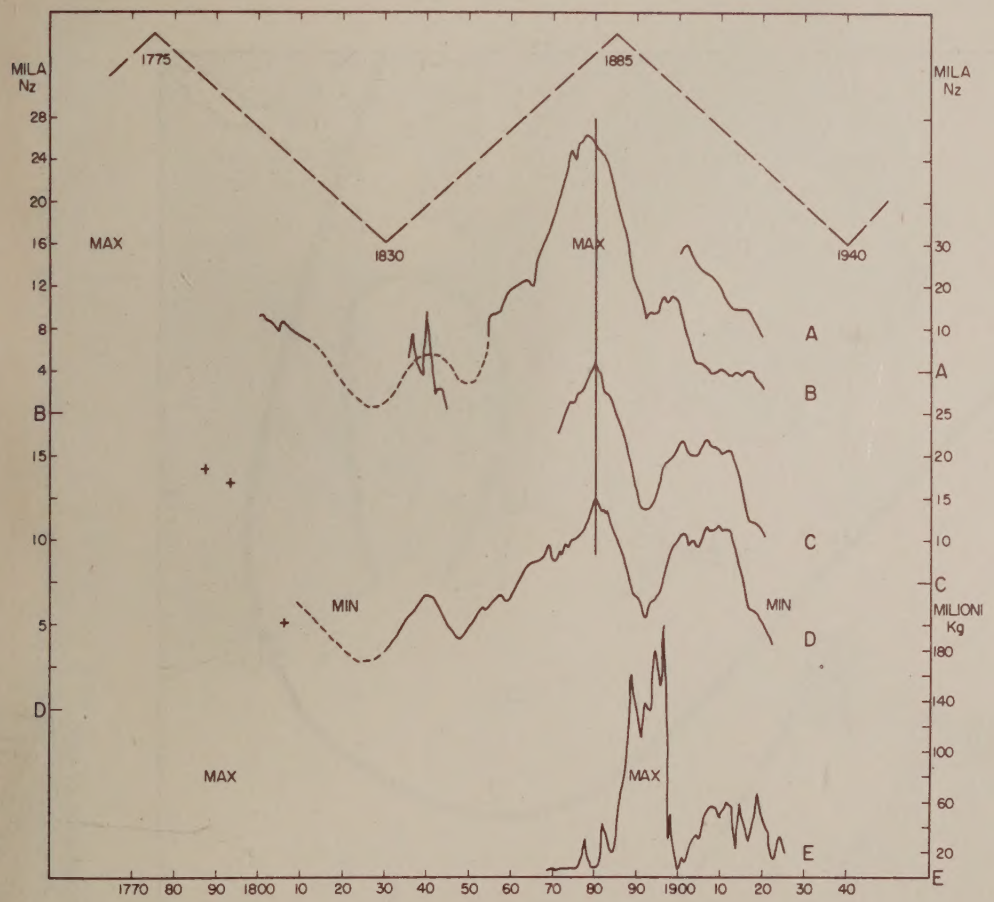

Figure 1. Diagram of the catches; smoothed by nine years, of the fisheries of: A, group of the Department of Tavira (Portugal); B, Medo das Cascas (Portugal); C, Sidi-Daud (Tunisia); D, P. Scuso I. Piana (Sardinia); E, fishery for herring at Bohuslan (Johansen), data not smoothed.

TN: The upper part of the vertical axis represents thousands of fish, the lower part millions of kilograms.

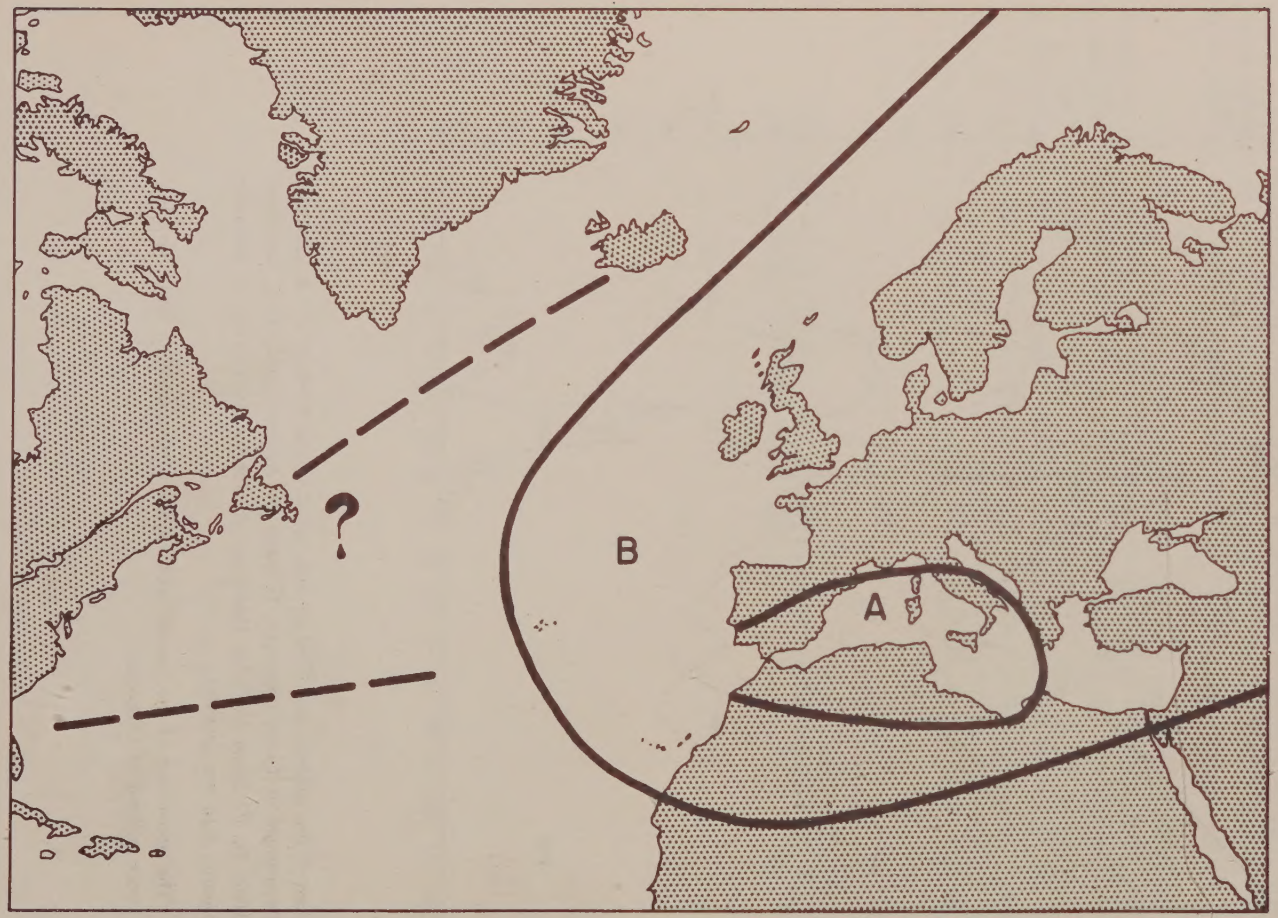

Figure 2. A, area of the spawning concentration of tuna.
B, area of the dispersion of the tuna which spawn in A, according to the evidence from hooks found up to the present.